OPERATING EXPERIENCE WITH 14.4/24.9 kv AS AN REA DISTRIBUTION VOLTAGE

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INTRODUCTION

In 1948, the need for a higher distribution voltage[1] for rural systems was pointed out. Since that time, a number of rural systems utilizing 14.4/24.9 kv grounded wye as a distribution voltage have been energized and considerable operating experience has been gained. In addition, equipment especially designed for this voltage has become available. Some standards and specifications for this equipment have been developed and others are being worked out. Operating problems which were encountered, such as excessive radio noise and lack of adequate sectionalizing devices are being solved by redesign of structures, redesign of equipment and development of new equipment by the manufacturers. All indications point to a more widespread use of 14.4/24.9 kv as a distribution voltage both for new systems and for the conversion of existing overloaded 7.2/12.5 kv systems.

EXTENT OF SYSTEMS

The use of 14.4/24.9kv as a distribution voltage is not new, distribution systems having been built to this voltage as early as 1900. It has been only since 1948, however, that systems using this voltage have been built extensively and systematically to bring power to sparsely settled areas.

Within the past four years 37 REA systems with a total of 10,988 miles of multiphase and single phase 14.4/24.9 kv distribution line have been energized and are now in operation. At the present time 32 systems have 9,695 miles of 14.4/24.9 kv distribution line under construction and 39 systems are planning on the construction of an additional 10,091 miles of such distribution line.

These systems are located in Arizona, Colorado, Florida, Georgia, Idaho, Iowa, Kansas, Maine, Michigan, Minnesota, Montana, Nebraska, New Mexico, North Dakota, Oregon, South Dakota, Texas, Washington, Wisconsin and Wyoming. Climatological conditions and terrain are varied, and the systems and equipment must be designed to withstand the most rigorous duty.

ECONOMICS

The basic economics of 14.4/24.9 kv as a distribution voltage have been pointed out previously.[1] A systematic procedure has since been developed for determining the conditions under which this voltage should be used.

Consideration is given to the use of 14.4/24.9 kv for the following:

1. New systems which ultimately would require transmission lines if distribution were at 7.2/12.5 kv.

2. New systems which would require conductor larger than No. 2 copper equivalent to carry the ultimate KW demand if distribution were at 7.2/12.5 kv.

3. New systems which ultimately will serve consumers more than 30 miles from the source of power.

4. Systems serving substantial power loads.

5. System improvements requiring transmission line and additional substations where distribution is now at 7.2/12.5 kv.

6. System improvements requiring larger than No. 2 copper equivalent where distribution is now at 7.2/12.5 kv.

The approach used in determining whether or not new systems should be constructed for 7.2/12.5 kv or 14.4/24.9 kv takes five general steps as follows:

1. Cost estimate using 7.2/12.5 kv with one substation.

2. Cost estimate using 7.2/12.5 kv with transmission and additional substations if necessary.

3. Cost estimate using 14.4/24.9 kv with one substation.

4. Cost estimate using 14.4/24.9 kv with transmission and additional substations if necessary.

5. Continuity of service.

6. Comparison and evaluation of losses in the system for the two voltages.

The overall cost, including transformers, of a new 14.4/24.9 kv system is about 20 percent higher than a new equivalent 7.2/12.5 kv system, assuming the same size conductor and phasing. On the other hand, since the line capacity is quadrupled, the construction cost per KW of capacity of the 14.4/24.9 kv system is approximately 30 percent of the 7.2/12.5 kv system of the same conductor size and phasing.

In determining whether a 7.2/12.5 kv distribution system should be converted to 14.4/24.9 kv, the following studies are made:

1. Cost estimate of conversion, utilizing autotransformers for 7.2 kv extensions where feasible.

2. Cost estimate using 7.2/12.5 kv plus additional transmission and substations.

3. Cost estimate of converting to 14.4/24.9 kv and extending such lines into new territory.

4. Continuity of service.

5. Comparison and evaluation of losses in the system for the two voltages.

Where the properselection of voltage is not obvious, a detailed study of the particular system is made for that purpose.

EQUIPMENT

When the first REA designed 14.4/24.9 kv distribution systems were built, lightning arresters, distribution transformers, and fuses of the 15 kv class were used in conjunction with nominal 23 kv pin type insulators, except at substations

where 25 kv class equipment was used throughout. Since that time, an almost complete line of equipment has been developed for use on these systems. Systems which are currently under construction normally will use equipment conforming to the following general requirements:

Pin Insulators	-Radio freed, nominal 23 kv, 95 kv dry flashover, 65 kv wet flashover.
Transformers	-18 kv class, demonstrated impulse withstand strength 125 kv full wave, 145 kv chopped wave, chopped at 2.5 microseconds.
Reclosers	-Nominal 23 kv, demonstrated impulse withstand strength 150 kv full wave, maximum interrupting rating not less than 750 amperes rms.
Lightning Arresters	-15 kv and 18 kv ratings acceptable, if guaranteed.
Sectionalizing fuses	-18 kv rating.
Substation equipment	-25 kv class.

In addition, all equipment must satisfy a very rigid radio noise test before acceptance for use on these systems.

EQUIPMENT PERFORMANCE

Paradoxically enough, less trouble and fewer failures have been reported with 15 kv class equipment than with some 18 kv class and 25 kv class equipment specially designed for these systems. Of particular interest is the satisfactory performance of the 15 kv arrester used from the beginning with 15 kv class transformers. Despite the fact that this arrester was installed extensively in severe lightning areas, its performance has been excellent. Anticipated difficulties because of recovery voltages and overvoltages have not materialized.

Likewise, the performance of 15 kv class transformers after three years continues to be satisfactory except for some objectionable radio noise, due principally to the bushing. However, some 18 kv and 25 kv class transformers were subject to the same defect before correction by the manufacturers.

Up to the present time, there appears to be little correlation between failure rate and insulation class of equipment used. The records indicate that the highest failure rate has been with some 18 kv arresters and 25 kv reclosers and transformers designed specially for these systems. In these cases, however, the cause of the failures can be traced to defects in design or manufacture and there is no evidence of a basic superiority of 15 kv class to 18 kv and 25 kv class equipment. On the basis of limited data it appears that the failure rate of 14.4/24.9 kv equipment is no greater than the failure rate of comparable 7.2/12.5 kv equipment except in those cases where defective design or manufacture is responsible for the difference.

DESIGN AND CONSTRUCTION

Standard REA design[2] was followed in the construction of the early 14.4/24.9 kv systems. Experience has shown the necessity, however, for changes in design, primarily to obtain increased clearances between energized parts and ground.

Where two inches of wood between the ridge pin and pole ground wire was adequate for 7.2/12.5 kv construction, the same clearance resulted in electrically overstressing the wood insulation of the pole and was the cause of excessive radio noise at 14.4/24.9 kv. It was found that a minimum of 12 inches of wood between hardware associated with energized parts and ground is necessary for satisfactory operation. To obtain this clearance, the design was revised to specify wood crossarm braces for some assemblies, to move guy wire locations and crossarms to a lower position on the pole, and to move the upper portion of the ground wire away from the surface of the pole, to form a horn gap.

In some cases a special ground wire staple has been used above the neutral to minimize the likelihood of loose ground wire staples. It has also been found necessary to dress the tie wires carefully to the phase wires or utilize a hot line tie with the ends looped to minimize radio interference difficulties.

Basic clearances to ground as specified by the National Electrical Safety Code[3] are somewhat different for 14.4/24.9 kv systems than for the lower voltage distribution systems. While the clearances for single phase lines are the same, the Code requires two feet additional clearance for multiphase sections of line, since the phase wires are within the voltage classification of 15,000-50,000 volts. This is particularly important in the conversion of 7.2/12.5 kv systems to 14.4/24.9 kv systems because it is invariably necessary to change out or install additional poles in multiphase sections of line to meet the Code requirements. Inasmuch as there appears to be no logical reason for this additional clearance, every effort is being made to have this requirement modified. The states of Arizona, Montana and South Dakota have, by legislative action, eliminated this Code requirement insofar as their state laws are concerned.

OPERATING PROBLEMS

Sectionalizing difficulties and excessive radio interference have been problems common to most of the earlier 14.4/24.9 kv systems. In addition a number of miscellaneous problems have arisen on individual systems which are attributable in whole or in part to the higher voltage.

Since higher voltage distribution systems are usually located in remote areas where radio signal strength is low, radio noise on the power system can be very objectionable.

Radio noise was found to originate from a variety of sources but in every case the basic cause proved to be overstressed insulation. A substantial part of the noise was traced to line design and construction practices, and to correct this condition, the changes in design and construction outlined previously were made on the later systems. The other major sources of noise were due to equipment such as line insulators, distribution transformers, reclosers, lightning arresters, etc. The use of radio freed insulators proved to be a ready solution for insulator noise. However, in other cases, it was necessary for the manufacturers

to redesign their equipment to meet the noise level desired. In practically every case, a high degree of cooperation was obtained with the result that equipment essentially free of radio noise is now available.

Although some of the older 14.4/24.9 kv systems are still noisy, much progress is being made by modification of installed equipment and changes in line construction. The newer systems are constructed to an improved design and with essentially satisfactory equipment; however, care must still be exercised in the details of construction to assure a quiet system.

Sectionalizing difficulties which have been experienced in the past were due principally to the lack of a 14.4/24.9 kv recloser. However, this condition has improved and reclosers designed for this voltage, are now available.

Low fault currents have been troublesome on several systems. In one extreme case where the source was a small diesel-generator, the minimum fault current at light load approached the maximum load current at peak conditions.

The question was raised at the time these systems were first proposed whether the continuity of service would be adversely affected by feeders 40 to 50 miles in length. Although it is too early to draw definite conclusions, there have been no reports which would indicate that the outage time is greater for these systems than for 7.2/12.5 kv systems. Perhaps the reason for this is that while the main feeders are longer, the total mileage protected by one sectionalizing device on 14.4/24.9 kv systems is comparable to the total mileage involved on 7.2/12.5 kv systems.

MISCELLANEOUS PROBLEMS

In areas of high ground resistance, it has been fairly common to find a potential gradient on the pole between the neutral and ground in addition to a relatively high gradient on the pole between the ridge pin and neutral. This potential gradient between neutral and ground can usually be lowered by the installation of additional ground rods.

Induced voltages on wire fences paralleling the distribution line have proved to be a problem at this voltage. Grounding of the fence at frequent intervals appears to be the most satisfactory solution.

High charging currents have been experienced on a number of systems for some time after energization. In some cases, this condition will be corrected as more load is added to the system. Irrigation loads constitute a substantial part of the load on other systems and since this is a seasonal load, it is likely that charging current will continue to be a problem during the seasons when the irrigation load is off.

While salt contamination of insulators is not a problem peculiar to higher voltage distribution systems, the effect is much more severe than at lower voltages. The effect on a 14.4/24.9 kv distribution system is also far more severe than on a transmission or sub-transmission line using the same voltage inasmuch as there are more leakage paths to ground over distribution transformer bushings, recloser bushings, lightning arrester porcelain, etc. One case of salt contamination has been reported on a 14.4/24.9 kv system which has proved difficult to correct. While some success was experienced with overinsulating the line, contamination of equipment bushings and lightning arresters remains as a problem which has not been solved.

CONCLUSIONS

With a development such as this it was to be expected that some new problems would arise. However, some of the more serious ones that had been predicted did not occur. The difficulties that have been encountered have been eliminated or reduced to such proportions that the operation of the 14.4/24.9 kv lines compare favorably with 7.2/12.5 kv lines. The experience of the past four years has justified the adoption of 14.4/24.9 kv as a standard REA voltage. It is anticipated that this higher voltage will be used to increase the capacity of existing systems. The use of this voltage has definitely been economical in the construction of new systems in territory that is not feasible to serve at lower distribution voltages.

REFERENCES

1. "Rural Distribution Voltages" and Discussion, W. M. Edmunds, G. B. Roloson, AIEE Transaction, Volume 67, 1948, Pages 1324-1326.

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3. "National Electrical Safety Code," National Bureau of Standards Handbook H32, Fifth Edition, Superintendent of Documents, Washington, D. C.